Constellation X

The Constellation X-Ray Mission

Project Scientist Report

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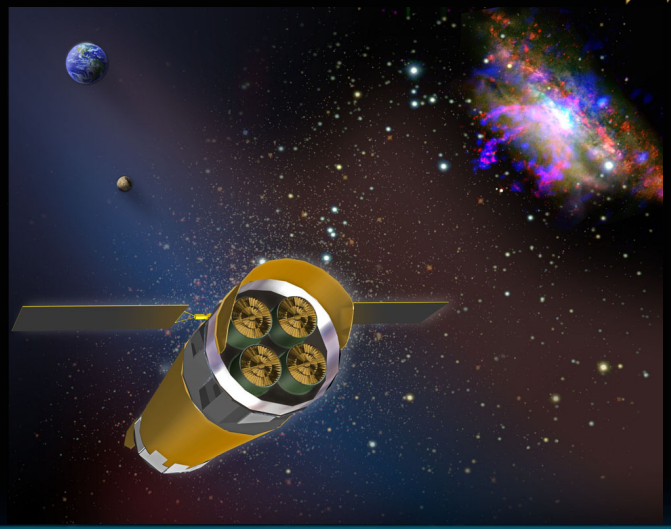
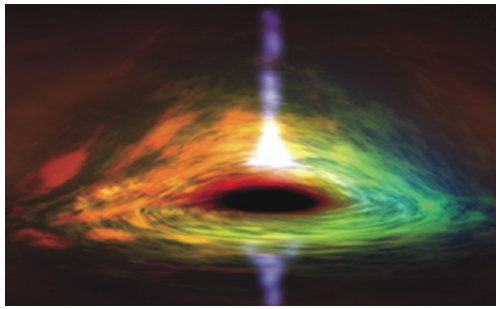


Opening the window of x-ray spectroscopy

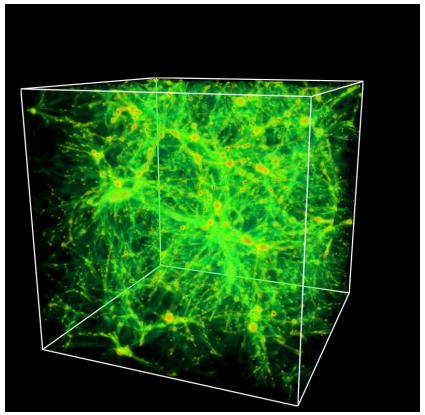
Constellation-X Science Objectives



Black Holes

Observe hot matter spiraling into **Black Holes** to test the effects of General Relativity

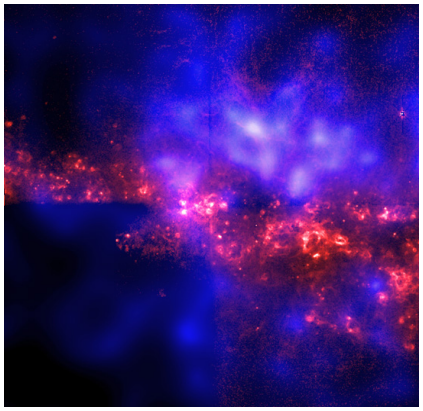
Trace their **evolution with cosmic time**, their contribution to the energy output of the Universe and their effect on galaxy formation



Large Scale Structure

Use clusters of galaxies to trace the locations of **Dark Matter** and follow the **formation of structure** as a function of distance

Search for the **missing baryonic matter** in the Cosmic Web

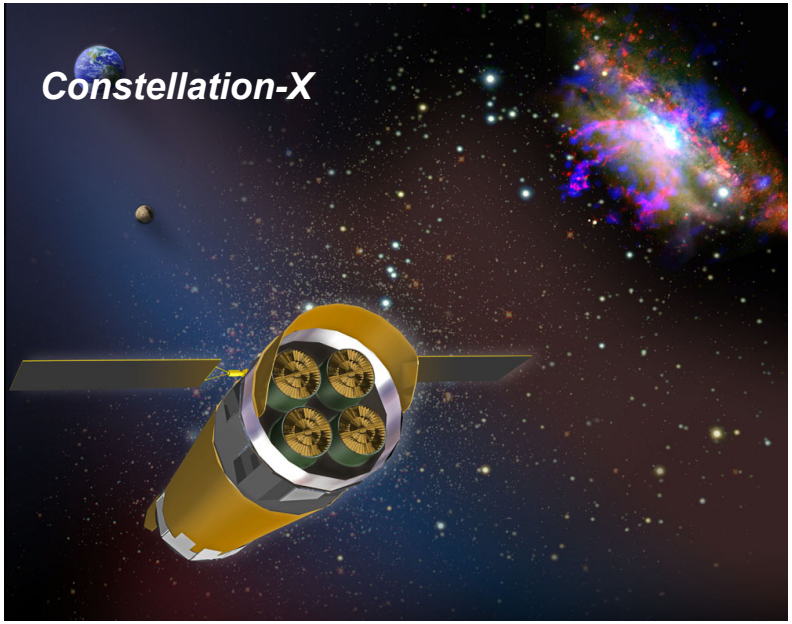


Cycles of Matter and Energy

Study dynamics of **Cosmic Feedback** (outflow of mechanical energy, radiation, and chemical elements from star formation and black holes to the interstellar and intergalactic medium)

Creation and dispersion of the elements in **supernovae**, The equation of state of **neutron stars, Stellar activity, proto-planetary systems** and X-rays from **solar system objects**

CONSTELLATION-X will open a new window on X-ray spectroscopy



The X-ray band is rich in diagnostic lines and features from the elements with atomic number from Carbon through to Zinc

Today only the very brightest sources have spectra with $E/\Delta E > 1000$, the nearest and brightest examples of each class

Most X-ray spectra currently available have moderate resolution CCD spectra $E/\Delta E < 30$, insufficient for diagnostics routinely available in other wavebands

Constellation-X has a resolution ($E/\Delta E$) of > 1250-2400 combined with a factor of 100 gain in effective area

Access all source populations over a wide range of source distance from nearby solar system objects to the most distant black holes (out at least to redshift 6 and beyond)

The next revolution in X-ray astronomy!

The physics is in the spectra: X-ray Astronomy becomes X-ray Astrophysics

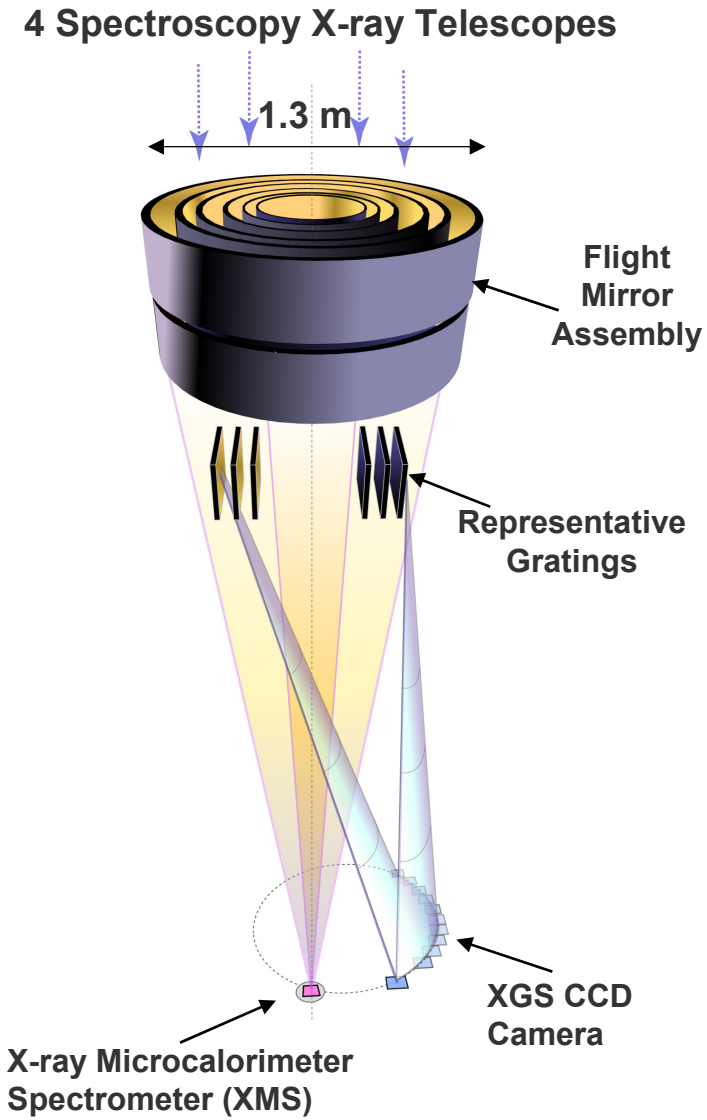
Science Objectives Flow Into Driving Performance Requirements

Effective Area:	15,000 cm^2 @1.25 keV 6,000 cm^2 @6 keV 150 cm^2 @40 keV	Black Hole evolution with time Large Scale Structure Black Hole Strong Gravity
Spectral Resolution:	1250 @0.3 – 1 keV (1,000 cm^2) 2400 @6 keV	Missing Baryons using many tens background AGN Large Scale Structure
Angular Resolution	15 arc sec (5 arc sec goal) 0.3 – 7 keV 30 arcsec 7.0 – 40 keV	Large Scale Structure Missing Baryons Black Hole Strong Gravity
Field of View	5 x 5 arcmin (10 x 10 arc min goal)	Large Scale structure
Count Rate	1,000 ct/sec/pixel	Neutron Star Equation of State

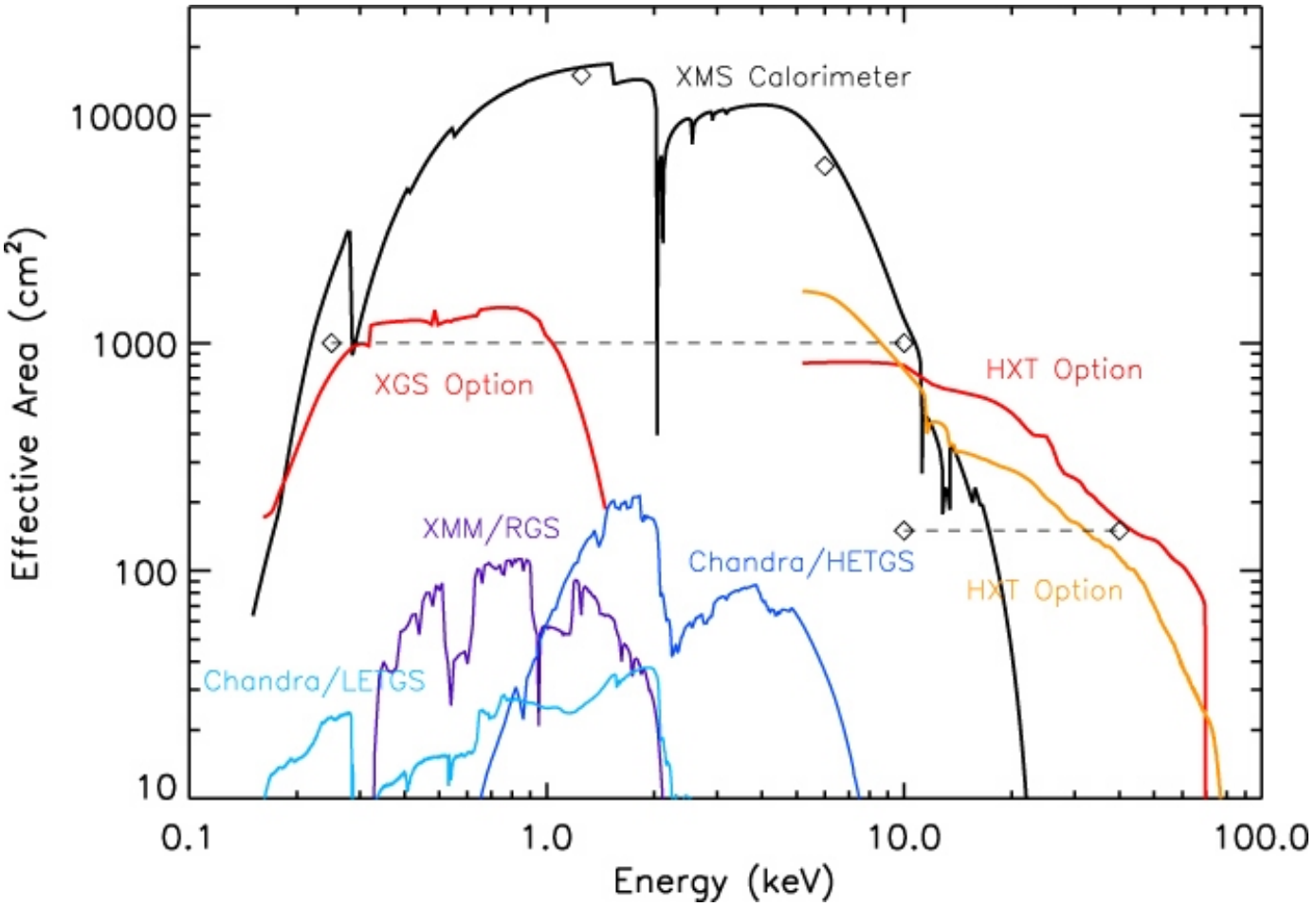
These capabilities enable great observatory science and open the window of X-ray spectroscopy for all classes of astrophysical objects from Comets to distant Quasars

Mission Implementation

- 4 Spectroscopy X-ray Telescopes (SXTs) each consisting of a Flight Mirror Assembly and a X-ray Microcalorimeter Spectrometer (XMS)
  - Covers the band-pass from 0.6 to 10 keV
  - Angular resolution requirement of 15 arc sec (goal of 5 arc sec HPD)
  - Field of View 5 x 5 arc min (64x64 pixels, goal of 10 x 10 arc min FOV)
  - Count rates: 1/4 crab or 1,000 ct/sec/pixel
- Two additional systems extend the bandpass:
  - X-ray Grating Spectrometer (XGS) covers from 0.3 to 1 keV (included in one or two SXT's)
  - Hard X-ray Telescope (HXT) band-pass covers from 6 to 40 keV (not shown)
- Instruments operate simultaneously

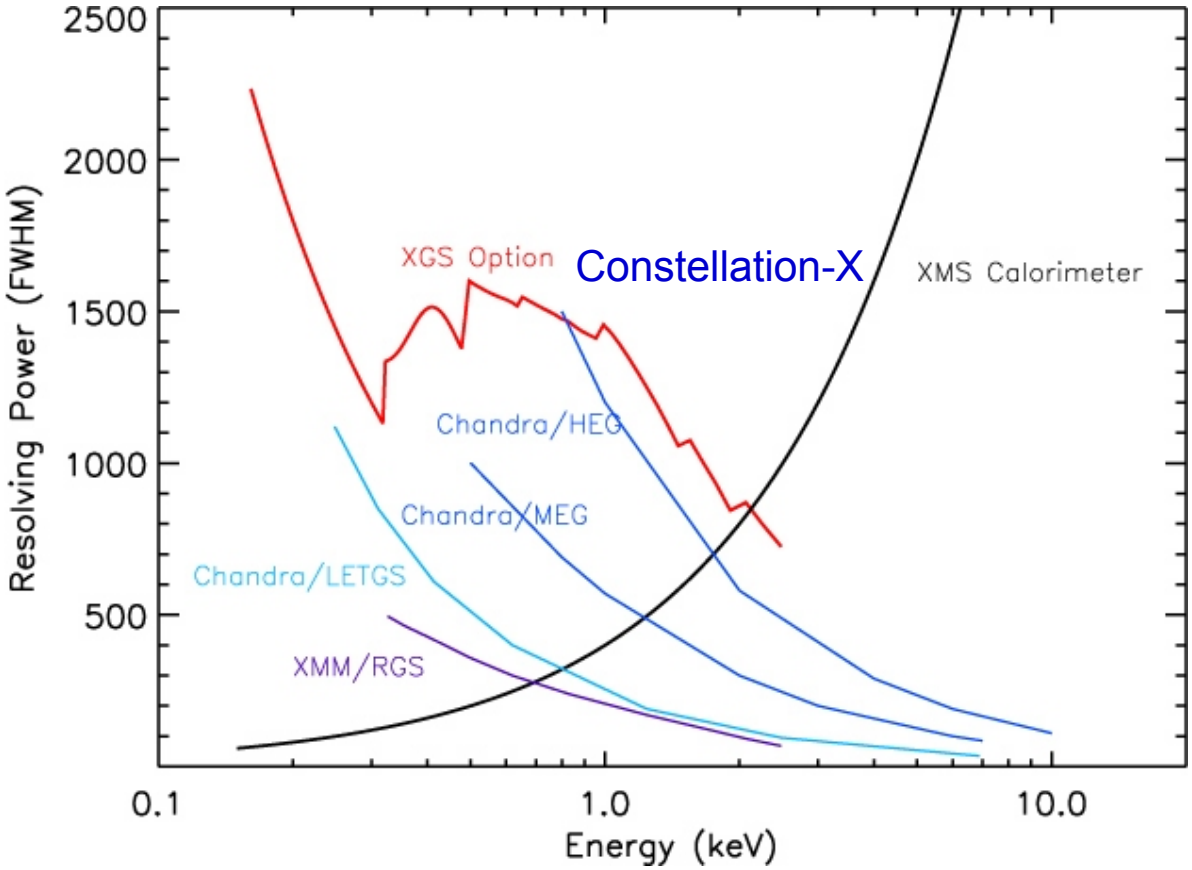


CONSTELLATION-X Effective Area Compared to previous missions



R > 1000 spectroscopy to a flux of 2 x 10^{-15} ergs cm^{-2} s^{-1} (0.1 to 2.0 keV), with 1000 counts in 100,000s, with a limiting sensitivity 10 times fainter

Spectral Resolution



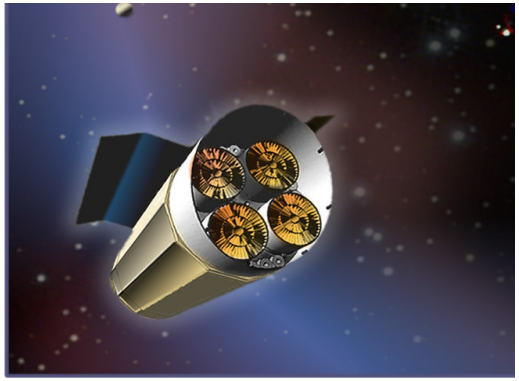
The Constellation-X energy band contains the K-line transitions of 25 elements Carbon through Zinc allowing simultaneous direct abundance determinations using line-to-continuum ratios, plasma diagnostics and bulk velocities of 200 km/s or better

Constellation-X Mission Configuration Evolution

2000 - 2004

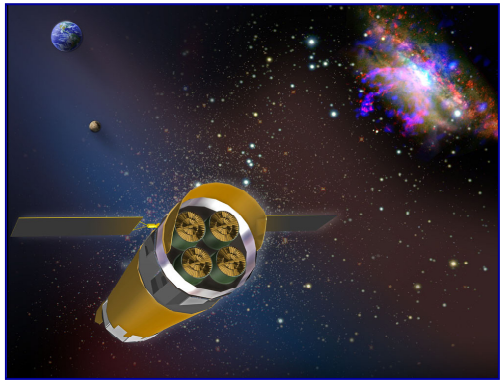
Two Atlas V 551

2005



Delta IV H

2006

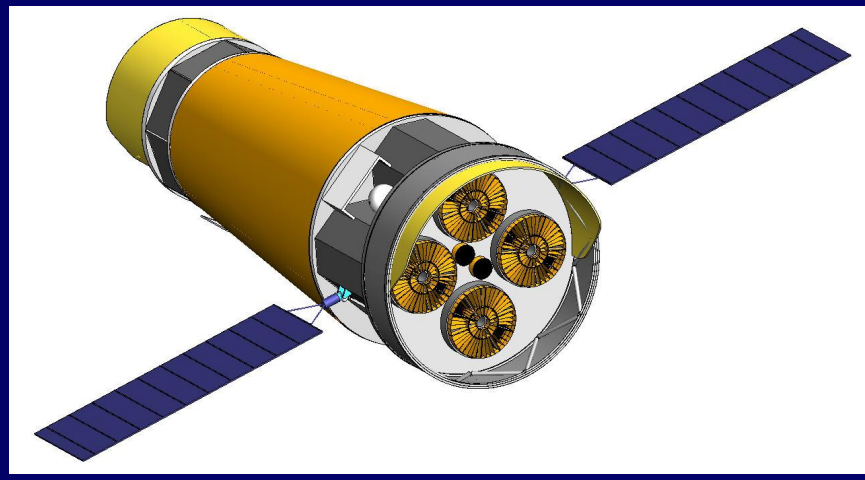


Atlas V 551

The Constellation-X design has evolved as pre-phase A mission studies have matured and in response to increased costs in the launcher market, while at the same time ***maintaining the core science capabilities***

Mission Implementation Approach

- Four X-ray telescopes with common design, manufacture, assembly, and testing
- Manageable mirror dimensions and 10m focal length provide required area
- Single spacecraft, single launch with proven subsystems and launch vehicles
- Mission success (via longer exposures) even with loss of one detector



Approach Reduces Risk and Costs

Some highlights from past year

- BEPAC process
  - "Con-X is one of the best studied missions in the Beyond Einstein program."
  - "Con-X will make the broadest and most diverse contributions to astronomy of any of the candidate Beyond Einstein missions."
  - "The committee concluded that the merits of Con-X can only be fully assessed when it is judged as a major astrophysics mission in a context broader than that of the Beyond Einstein program."
- Technology progress continues to make great progress e.g.
  - First X-ray test of a reflector pair, close to mission requirements
  - First multiplexed calorimeter array, close to mission requirements

Astrophysics Program Content

	* FY07	* FY08	FY09	FY10	FY11	FY12	FY13
FY09 President's Budget *	1,356.8	1,363.4	1,164.5	1,122.4	1,057.1	1,067.7	1,116.0
Physics of the Cosmos	196.5	157.2	157.0	219.8	249.0	271.1	326.0
GLAST	84.4	41.9	23.2	23.3	24.1	24.9	24.9
Herschel	11.5	14.9	27.2	17.4	17.6	17.5	16.4
Planck	6.7	8.8	9.4	8.9	6.6	6.5	6.5
JDEM		3.7	8.5	63.0	83.0	109.0	125.0
LISA	6.5	5.7	5.7	15.9	18.7	26.7	35.0
Constellation-X	8.3	8.1	8.3	12.0	16.8	15.9	42.0
Other Missions and Data Analysis	79.1	74.1	74.9	79.3	82.1	70.6	76.2
Exoplanet Exploration	184.6	159.5	48.1	67.7	68.4	96.4	126.2
SIM	30.4	24.3					
Kepler	121.8	79.5	25.2	14.9	13.9	12.6	8.8
Future Exoplanet Missions	1.0	23.8	6.6	41.7	44.0	72.0	107.5
Other Missions and Data Analysis	31.3	31.9	16.3	11.2	10.5	11.7	9.9
Cosmic Origins	788.9	816.9	674.4	571.1	515.4	485.6	458.5
James Webb Space Telescope	398.6	447.4	371.9	311.1	265.1	236.1	194.9
Hubble Space Telescope	277.5	230.2	154.9	125.6	114.7	94.8	93.9
SOFIA	38.9	64.0	72.8	72.8	57.0	58.8	60.6
Spitzer	73.8	75.4	71.7	15.9	10.3	3.2	3.3
Astrophysics Future Missions			3.0	45.8	68.3	92.7	105.8
Astrophysics Explorer	88.0	117.2	132.6	93.3	43.3	11.7	6.4
WISE	52.9	72.7	65.2	13.0	5.2	1.6	
NuSTAR		16.7	43.5	57.8	31.0	6.8	6.4
Operating Explorers	35.1	27.8	23.9	22.5	7.1	3.2	
Astrophysics Research	98.8	112.6	152.3	170.4	181.0	203.0	198.9
Research and Analysis	52.2	56.6	61.4	65.4	69.3	72.6	77.5
Balloons	22.2	24.0	24.6	26.7	28.8	32.4	33.2
Other Missions and Data Analysis	24.5	32.0	66.3	78.4	82.9	97.9	88.2

*** FY07 and FY08 reflect latest Operating Plan, in FY09 structure**

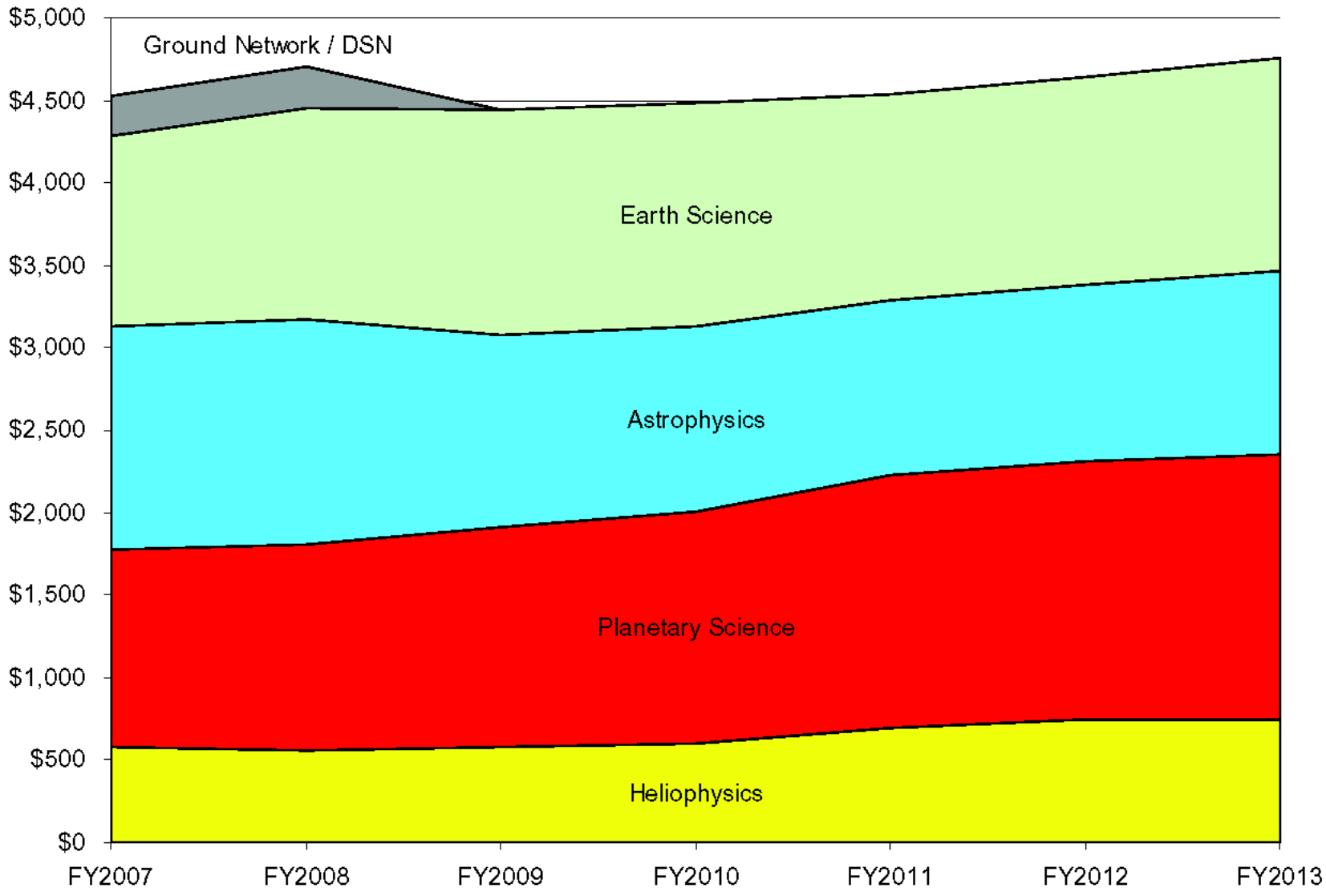
Astrophysics Budget Changes

	FY07	FY08	FY09	FY10	FY11	FY12	07-12 Total
Content Changes from FY08	26.5	40.3	-4.4	-36.6	-72.9	-143.7	-190.8
JDEM		3.7	8.5	63.0	83.0	109.0	267.2
LISA	-3.3	0.7	0.5	11.0	14.0	23.0	45.8
Constellation-X	3.3	3.0	3.0	7.0	12.0	12.0	40.3
Physics of the Cosmos Future	-0.2	-14.2	-30.8	-108.1	-125.8	-164.4	-443.5
SIM	-63.8	4.1	-20.7	-22.0	-22.3	-22.6	-147.3
Future Exoplanet Missions		22.8	5.6	40.7	42.8	70.3	182.2
Michelson Science Center	1.5	-2.5	-5.5	-8.5	-10.2	-10.2	-35.4
SOFIA	38.9	0.9	-0.1	-0.1	-17.1	-17.1	5.4
Balloons	2.4	2.0	0.5	2.8	5.0	7.3	20.0
Research and Analysis	2.1	9.0	12.5	19.2	21.2	22.8	86.8
Hubble Space Telescope	-7.0	3.6	19.7		-10.0	-30.0	-23.7
Spitzer / Chandra	-5.0			-33.0	-34.0	-60.0	-132.0
Herschel	-0.2	0.4		-10.0	-10.0	-10.0	-29.8
Kepler	32.6		3.8	1.5	0.5	-1.8	36.6
GLAST	9.2	7.5					16.7
Astrophysics Future			2.8	3.1	-9.8	-71.9	-75.8
All other	16.0	-0.8	-4.2	-3.2	-12.2	-0.1	-4.5

Astrophysics Budget Restructure Crosswalk

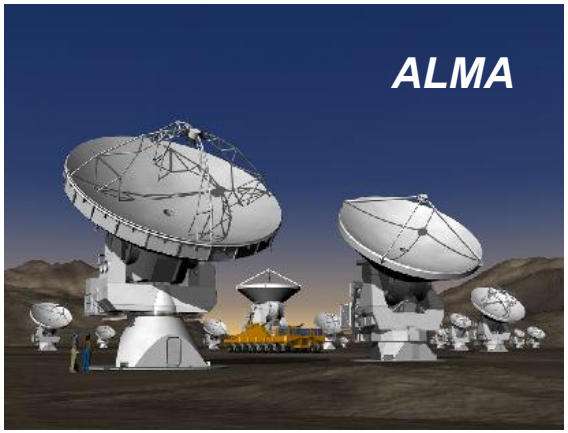
Current Structure	New Structure
Navigator Discovery (Kepler)	Exoplanet Exploration "Are we Alone?"
JWST HST SOFIA Spitzer	Cosmic Origins "How did we get here?"
Beyond Einstein GLAST ISSC Chandra	Physics of the Cosmos "How does the Universe Work?"
Astro. Explorers	Astrophysics Explorer (Adds operating missions)
Astro. Research	Astrophysics Research (Subtracts operating missions)

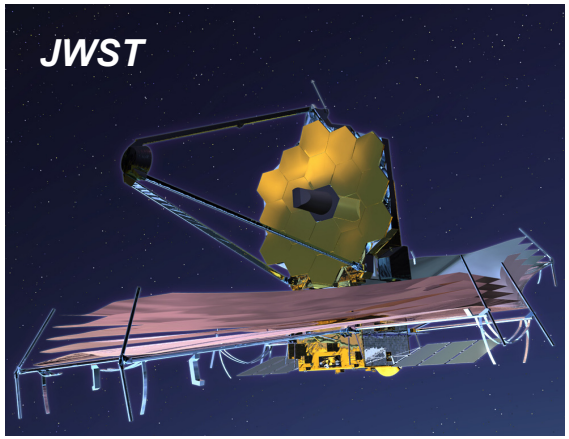
SMD BUDGET BY SCIENCE THEME



Constellation-X: A future astrophysics great observatory

Sub-mm





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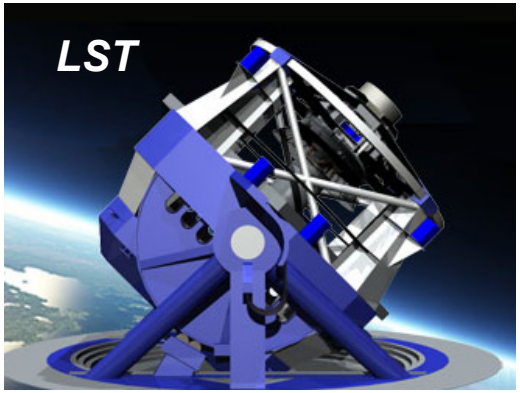

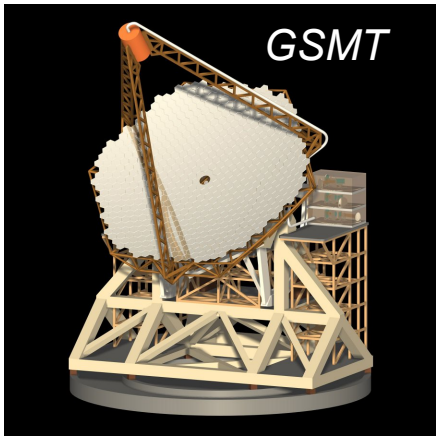

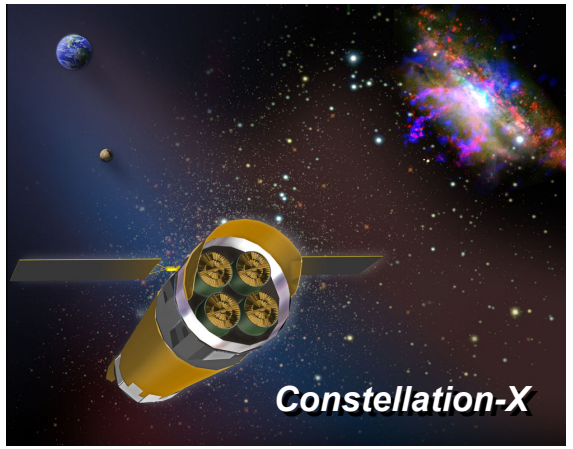

X-ray

Optical

The two order of magnitude increase in capability of Constellation-X is well matched to that of other large facilities planned for the 2010-2020 decade

Upcoming 2010 Decadal Survey

- Constellation-X is currently the number 2 priority from the 2000 survey and as such HQ is treating the mission as the next large astrophysics observatory to follow after JWST
- Constellation-X science case has strengthened over the past decade, with many new discoveries e.g. the importance of Cosmic Feedback now being central to Con-X science case
- Constellation-X is an “observatory flagship class” mission that brings a two order of magnitude increase in capability, and will have broad appeal across the Astrophysics community
- It is important the science case be made in the context of broad astrophysics problems and questions
- It is important that we put forward the most exciting science that the mission will undertake as the most compelling problems that only Con-X will address

Summary

- Constellation-X is a great observatory that opens the window of X-ray spectroscopy with a two order of magnitude gain in capability that will make major advances in the study of virtually all classes of astrophysical object, and will specifically:
  - Revolutionize our understanding of how Black Holes evolve with cosmic time, and observe matter orbiting close to the event horizon
  - Follow the formation of large scale structure through observations of clusters of galaxies and search the Cosmic Web to find the missing hot Baryons
  - Study the processes that drive Cosmic Feedback, the formation of the elements and their distribution throughout the Universe
- We are realizing the payoff from many years of well focused technology investments and mission implementation studies that demonstrate the mission is ready to proceed
- We are poised to make a robust case to the upcoming decadal survey that Constellation-X is the highest priority for the next large astrophysics observatory

http://constellation.gsfc.nasa.gov